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Seed Quality Deterioration of Tomato during Storage: Effect of Storing Containers and condition

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ABSTRACT: Tomato is the highly nutritious vegetables crop. By consumption of crops, it will provide the nutritional security of people. It has been assertively and emphatically shown that 15-20% increased yield could be achieved by the use of good quality seeds alone. Good quality seed is one of the most important requirements for production and supply to achieve higher production and productivity in any crop. The seed quality is depended on various factors Viz. genetic, edaphic, environmental, biotic, etc. Complex conditions evoking the most favourable interactions between the genetic makeup of the seed and the environment, under which it is produced, harvested, processed, and stored, require maintaining good quality seed. During storage, seeds undergo deterioration resulting in a decline in germination and vigour. With this view, the present investigation has been undertaken to determine seed quality of tomato after harvesting in 2020-2021 at Seed Testing Laboratory, Department of Seed Science and Technology, BCKV, Mohanpur, Nadia, West Bengal, India. There were no effect of different containers and condition at immediately after harvest the seed. Refrigerated condition was the best among the other containers and condition. Because, the average value over duration of germination percentage; vigour index; soluble protein content of seeds; total carbohydrate content recorded highest and lowest value of electrical conductivity was recorded in refrigerated condition. The average germination potential was gradually decrease during different period of storage i.e., 84.11%, 78.35%, 74.12% and 66.85% in 2^nd^ month, 4^th^ month, 6^th^ month and 8^th^ months respectively. Similar trends were recorded in vigour index also. The minimum germination percentage was maintained upto 8^th^ month of storage in refrigerated condition.

Keywords: Tomato**,** seed deterioration, containers and condition, germination, vigour, seed storage.

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is a member of Solanaceae family which is well known for a number of medicinal and nutritional properties. Botanically, this fruit is known as berry (Salunkhe *et al*., 2005). Thousands of varieties of tomatoes have been reported in terms of shapes, colours and size. Tomato seeds have a high commercial value, and the loss of seed physiological quality over time is demonstrated by their low storability unless hermetic conditions are used (Tigist *et al*., 2012). To achieve nutritional security of people, consumption of crops like tomato may be increased (Sivakumar, 2021). Laxman *et al.* (2021) reported that in hybridization program for tomato crop may useful in the conservation and also exchange of the germplasm. Mohammadi *et al.* (2019) showed that control had the lowest level of acidity compared to the treatments indicating that the essential oils of cinnamon, fennel, and clove prevented the transformation of organic acids in date fruit to other materials including sugars during storage. Seed persistence is vital in temporally unpredictable environments, because after unfavourable years a population may become extinct, whereas a persistent seed bank may buffer such years (Ray and Bordolui, 2021). Seeds undergo deterioration at various levels during storage resulting in decline in a vigour and viability (Bordolui *et al.*, 2015). In next generation, the success of seeds depends on an important post-harvest operation, known as seed storage. The main purpose of seed storage is to preserve economic crops from one season to another. Storage temperature and moisture content are the most important factors affecting seed longevity, with seed moisture content usually being more influential than temperature. Several environmental factors have been reported to affect seed viability during storage. Some of the factors that affect the longevity of seeds in storage could be genotype of crop, initial seed quality, storage containers and conditions. Several studies have indicated that storage containers affected the seed quality in terms of germination and viability over a period of time (Bortey *et al*., 2016; Moharana *et al*., 2017; Bordolui *et al.*, 2021). However, it has been reported that the intensity of decreasing the quality of stored seed under different storage techniques differ among plant species and within plant species as well as among varieties (Al-Yahya, 2001; Kumari *et al*., 2017). Packaging materials play a major role in extending the storability of the seeds. The moisture proof containers will inhibit the exchange of the moisture between the seeds and the surrounding atmosphere resulted in enhanced storability. Packaging container and storage duration significantly affected viability and seedling vigour (Rao *et al*., 2006; Chakraborty *et al*., 2020). Seeds must be properly stored in order to maintain an acceptable level of germination and vigour until the time of planting. There is an increasing awareness of saving both time and expense that are realized by using suitable moisture proof containers for storing valuable breeding stocks. The objective of this study was to identify tomato genotype towards different storage containers and conditions.

MATERIALS AND METHODS

The laboratory experiment was carried out in seed testing laboratory, Department of Seed science and Technology, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal, India, during 2020-21 following Complete Randomized Design with three replications. The seed material for the present investigation is comprised of one tomato genotype viz., BCT-25. Immediately after harvesting, seeds were properly sun-dried to its safe moisture content of tomato were collected from control plot of the genotype for each replication and were stored in different packaging materials and condition, such as Cloth bag (T_1), Aluminium foil pouch (T_2), Brown paper packet (T_3), Earthen pot (T_4), 700 gauge Polythene packet (T_5) leaving no air or minimum air space and within Refrigerator (T_6) at around 4 ^{0}C. Different physiological seed quality parameters such as root length (cm), shoot length (cm), seedling length (cm), germination percentage, vigour index, fresh weight (g) of ten seedlings and dry weight (g) of ten seedlings as well as biochemical parameters such as electrical conductivity (ds m^{-1}), soluble protein content (mg g^{-1}) and total carbohydrate content (mg g^{-1}) of differently stored seeds were recorded at every two months interval up to eight months of storage.

RESULTS AND DISCUSSION

Seedling parameters, germination percentage, vigour index and biochemical properties of tomato seed at just after harvest: At initial stage, i.e., immediately after harvesting, seeds were kept for germination test, recording seedling parameters, vigour index as well as biochemical properties of seeds were analysed. Initially, root and shoot length of seedling was recorded as 9.76 cm and 4.22 cm respectively, which indicated the seedling length of 13.98 cm (Table 1). Seed germination percentage was noted to be 92.87 and vigour index was 1298.32. Fresh weight and dry weight of seedlings were 0.160 g and 0.017 g respectively. Just after harvesting, electrical conductivity of seed leachates were 0.113dS m^{-1} g^{-1}. Soluble protein content and total carbohydrate content of seed were noted to be 2.829 mg g^{-1} and 2.872 mg g^{-1}.

Table 1: Seedling parameters, germination percentage, vigour index and biochemical properties of seed at just after harvesting.

Sr. No.	Seed and seedling quality parameters	Value just after harvesting
1.	Root length (cm)	9.76
2.	Shoot length (cm)	4.22
3.	Seedling length (cm)	13.98
4.	Germination percentage	74.48 (92.87)
5.	Vigour index	1298.32
6.	Fresh weight of ten seedlings (g)	0.160
7.	Dry weight of ten seedlings (g)	0.017
8.	Electrical conductivity of seed leachates (dS m^{-1} g^{-1})	0.113
9.	Soluble protein content of seed (mg g^{-1})	2.829
10.	Total carbohydrate content of seed (mg g^{-1})	2.872

Root length (cm): During different storage durations root length of seedling was varied significantly when average was made over storage containers and condition considered as treatment (T); seedling root length at fourteen days after setting was found maximum in D_1 (9.18 cm) and with the advancement in storage duration it automatically declined, though D_2, D_3 and D_4 were statistically at per with each other (Table 2). Significant variation was displayed by the treatments, when average was taken over the storage durations (D); it was noted longest in T_6 (9.43 cm), followed by T_5, T_2, T_3, although T_6, T_5, T_2 and T_2, T_3 were statistically non-significant and shortest root length was found in T_1 (7.84 cm). While considering the combined effect of storage durations and storage treatments, it showed non-significant variation for the trait; highest value of root length was observed in D_1T_6 (9.70 cm) and lowest value was obtained in D_4T_1 (7.25 cm). As the time of storage progresses, a declining trend in root length was noticed for each treatment. Similar type of finding was noted by Geetanjali *et al*. (2019) in onion seeds with respect to the production of higher seedling root length after stored in commercial storage condition at 5-7 °C and 65% relative humidity.

Table 2: Effect of storage containers and condition on root length (cm) of seedling over the period of storage.

	T_1	T_2	T_3	T_4	T_5	T_6	Mean D
D_1	8.83	9.54	9.21	8.28	9.54	9.70	9.18
D_2	7.63	9.07	9.10	8.27	9.33	9.60	8.83
D_3	7.63	9.06	9.08	8.17	9.25	9.24	8.74
D_4	7.25	9.05	8.95	8.04	9.23	9.19	8.62
Mean T	7.84	9.18	9.09	8.19	9.34	9.43	
	D	**T**	**D X T**				
SEm(±)	**0.095**	**0.117**	**0.233**				
LSD (0.05)	**0.271**	**0.332**	-				

Note: D = Durations, D_1 = Two months, D_2 = Four months, D_3 = Six months, D_4 = Eight months, **T** = Treatment, T_1 = Cloth bag, T_2 = Aluminium foil, T_3 = Brown paper packet, T_4 = Earthen pot, T_5 = Polythene packet, T_6 = Refrigerator.

Shoot length (cm): Significant variation was observed for seedling shoot length, when average was taken over treatments; maximum shoot length was recorded in D_1 (3.94 cm) and it was minimum in D_4 (3.61 cm) (Table 3); a trend in decrease in shoot length was noted over the month of storage. Storage treatments showed significant variation over durations, where longest shoot was produced by T_6 (3.92 cm), followed by T_2, T_3, T_5, T_4, though T_6, T_2 and T_3, T_5, T_4 noted statistically similar values for the seedling parameter, while T_1 produced shortest shoot (3.52 cm). Significant variation was observed for interaction effect of storage duration and storage treatment similar to seedling root length; D_1T_2 exhibited longest shoot length (4.18 cm), though D_1T_2 and D_1T_5 were statistically non-significant, whereas, D_4T_1 produced shortest shoot (3.38 cm), although D_4T_1, D_4T_5, D_3T_1 were statistically at per with each other and length of shoot was reduced for each storage treatment with the advancement of storage duration. Venge *et al*. (2016) in soybean and Patel *et al*. (2017) in onion showed similar type of findings with respect to seedling root and shoot length during storage.

Table 3. Effect of storage containers and condition on shoot length (cm) of seedling over the period of storage:

	T_1	T_2	T_3	T_4	T_5	T_6	Mean D
D_1	3.62	4.18	3.93	3.81	4.13	4.00	3.94
D_2	3.56	3.84	3.80	3.74	3.87	3.95	3.79
D_3	3.53	3.79	3.80	3.68	3.70	3.92	3.74
D_4	3.38	3.70	3.63	3.68	3.45	3.81	3.61
Mean T	3.52	3.88	3.79	3.73	3.79	3.92	
	D	**T**	**D X T**				
SEm(±)	**0.023**	**0.028**	**0.056**				
LSD (0.05)	**0.065**	**0.080**	**0.160**				

Note: D = Durations, D_1 = Two months, D_2 = Four months, D_3 = Six months, D_4 = Eight months, **T** = Treatment, T_1 = Cloth bag, T_2 = Aluminium foil, T_3 = Brown paper packet, T_4 = Earthen pot, T_5 = Polythene packet, T_6 = Refrigerator.

Seedling length (cm): When average was measured over the treatments, the mean value of storage durations varied significantly for seedling length; it was recorded to be maximum at D_1 with 13.13 cm and decreased as the storage duration increased, indicating the minimum length of 12.23 cm at D_4, though D_2, D_3 and D_3, D_4 were statistically similar (Table 4). Average performance of storage treatments showed significant variation; length of seedling was noted to be longest for T_6 (13.36 cm), followed by T_5, T_2, T_3, though T_6, T_5, T_2 were statistically non-significant for the trait and it was shortest for T_1 (11.36 cm). Similar to the root length, seedling length was non-significantly influenced by storage treatments with response to durations; where, longest seedling was produced by D_1T_6 and shortest by D_4T_1 and a similar trend of decreasing the seedling length was observed for each treatment as there was progress in storage period. This was in conformity with Venge *et al*. (2016) in soybean and Geetanjali *et al*. (2019) in onion seeds with respect to higher root and shoot length of seedlings.

Table 4: Effect of storage containers and condition on seedling length (cm) over the period of storage.

	T_1	T_2	T_3	T_4	T_5	T_6	Mean D
D_1	12.45	13.72	13.14	12.09	13.67	13.70	13.13
D_2	11.19	12.90	12.90	12.01	13.20	13.55	12.63
D_3	11.16	12.84	12.88	11.85	12.95	13.17	12.47
D_4	10.63	12.75	12.59	11.72	12.68	13.01	12.23
Mean T	11.36	13.05	12.88	11.92	13.13	13.36	
	D	**T**	**D X T**				
SEm(±)	**0.090**	**0.110**	**0.221**				
LSD (0.05)	**0.257**	**0.314**	-				

Note: D = Durations, D_1 = Two months, D_2 = Four months, D_3 = Six months, D_4 = Eight months, **T** = Treatment, T_1 = Cloth bag, T_2 = Aluminium foil, T_3 = Brown paper packet, T_4 = Earthen pot, T_5 = Polythene packet, T_6 = Refrigerator.

Germination percentage: Significant influence of storage period could be noticed on germination potential of the genotype, when average was made over the treatments. Consistent reduction in average germination potential, i.e., D_1 (84.11%), D_2 (78.35%), D_3 (74.12%) and D_4 (66.85%), could be revealed through (Table 5) and it attained the lower magnitude than the prescribed value under MSCS at eight months after storage (D_4). Kartoori and Patil (2018) noted similar trend of decreasing germination percentage in onion seeds as the storage duration increased. While considering the average performance of the storage treatments, variation in the germination potential was found to be significant. T_6 (78.39%) exerted significantly highest influence average over durations in comparison to that of other storage conditions and it was followed by T_5, T_2, T_3, T_4 and T_1. While analysis was made for influence of storage durations on different storage conditions, it showed significant variation for germination potential and almost similar trend could be noticed as could be revealed for average influence of the storage conditions and the germination percentage fell below the minimum standard prescribed by MSCS at eight months after storage irrespective of the storage conditions; highest germination percentage was recorded in D_1T_6 (86.92) and lowest in D_4T_1 (63.55). The result is in conformity with Ray and Bordolui (2020) in marigold, where it was observed that marigold seeds kept in refrigerator recorded higher germination percentage at the end of storage period. Considering the prescribed germination percentage under MSCS for Tomato vis-à-vis the experimental findings recorded here in for this important parameter, recommendation can be made for safe storage till six months of storage under the storage conditions included in the present investigation.

Table 5: Effect of storage containers and condition on germination (%) of seeds over the period of storage.

	T_1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**	**Mean D**
D_1	64.86 (81.99)	66.68 (84.36)	66.24 (83.80)	65.25 (82.51)	67.26 (85.09)	68.77 (86.92)	66.51 (84.11)
D_2	60.69 (76.07)	62.09 (78.13)	61.96 (77.94)	61.59 (77.40)	63.27 (79.80)	63.97 (80.78)	62.26 (78.35)
D_3	58.39 (72.56)	59.47 (74.23)	59.24 (73.87)	58.76 (73.13)	59.98 (75.01)	60.57 (75.89)	59.40 (74.12)
D_4	52.84 (63.55)	55.00 (67.14)	54.49 (66.30)	53.82 (65.18)	56.11 (68.94)	56.74 (69.96)	54.83 (66.85)
Mean T	59.20 (73.54)	60.81 (75.96)	60.48 (75.48)	59.85 (74.56)	61.65 (77.21)	62.51 (78.39)	
	D	**T**	**D X T**				
SEm(±)	**0.034**	**0.042**	**0.084**				
LSD (0.05)	**0.098**	**0.120**	**0.240**				

Note: D = Durations, **D_1** = Two months, **D_2** = Four months, **D_3** = Six months, **D_4** = Eight months, **T** = Treatment, **T_1** = Cloth bag, **T_2** = Aluminium foil, **T_3** = Brown paper packet, **T_4** = Earthen pot, **T_5** = Polythene packet, **T_6** = Refrigerator.

Vigour index: Storage duration varied significantly for vigour index, when average was made over the storage treatments; highest magnitude of vigour was calculated at D_1 (1105.13) and over the period it decreased. Significant variation was noted among the storage treatments; maximum vigourous seedlings were determined for T_6 (1048.56), followed by T_5, T_2, T_3, T_4 and T_1 (Table 6). Influence of storage duration on storage treatments noted significant variation for vigour index; vigour was reduced for each treatment with the advancement in storage duration, where it was recorded highest for D_1T_6 (1190.56) and lowest for D_4T_1 (675.78). Basavegowda *et al*. (2013) recorded highest vigour index in chickpea seeds stored under commercial storage at 5-7 °C and 65% relative humidity. Ray and Bordolui (2020) recommended seed storage within refrigerator packed in polythene packet for marigold genotypes to maintain higher quality of seeds with respect to germination potential and vigour index. The reason behind maintaining higher vigour in cold storage condition as compared to other storage containers is due to reduced rate of respiration and metabolic changes occurred in seeds as reported by Das *et al*. (1998) in Rajmah seeds.

Table 6: Effect of storage containers and condition on vigour index of seedling over the period of storage.

	T_1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**	**Mean D**
D_1	1,020.78	1,157.37	1,101.13	997.55	1163.42	1190.56	1105.13
D_2	851.19	1,008.14	1,005.64	929.61	1053.40	1094.52	990.42
D_3	810.05	953.32	951.49	866.39	971.13	999.22	925.27
D_4	675.78	856.04	834.54	763.69	874.12	909.95	819.02
Mean T	839.45	993.72	973.20	889.31	1015.52	1048.56	
	D	**T**	**D X T**				
SEm(±)	**0.463**	**0.567**	**1.134**				
LSD (0.05)	**1.320**	**1.617**	**3.234**				

Note: D = Durations, **D_1** = Two months, **D_2** = Four months, **D_3** = Six months, **D_4** = Eight months, **T** = Treatment, **T_1** = Cloth bag, **T_2** = Aluminium foil, **T_3** = Brown paper packet, **T_4** = Earthen pot, **T_5** = Polythene packet, **T_6** = Refrigerator.

Fresh weight (g): Fresh weight of ten seedlings was recorded ant it was declined at a minute rate as the period of storage progressed, though storage durations showed non-significant variation for the trait; maximum weight of 0.139 g was recorded in D_1, while it was minimum in D_4 (0.131 g) (Table 7). When average was made over duration, it was observed significant variation by the storage treatments for the parameter; highest fresh weight was noted for T_6 (0.154 g), followed by T_5, T_2, T_3, though non-significant difference could be noticed between the treatments and it was lowest for T_1 (0.116 g). Similar type of observation was reported by Kandil *et al*. (2013) in soybean. Non-significant variation was indicated by the combined effect of storage treatments and durations for fresh weight of seedlings.

Table 7: Effect of storage containers and condition on fresh weight (g) of seedlings over the period of storage.

	T_1	T_2	T_3	T_4	T_5	T_6	Mean D
D_1	0.129	0.142	0.138	0.122	0.145	0.158	0.139
D_2	0.115	0.139	0.135	0.123	0.144	0.158	0.136
D_3	0.112	0.137	0.134	0.121	0.143	0.151	0.133
D_4	0.109	0.136	0.133	0.119	0.142	0.149	0.131
Mean T	0.116	0.138	0.135	0.121	0.144	0.154	
	D	**T**	**D X T**				
SEm(±)	**0.005**	**0.006**	**0.011**				
LSD (0.05)	**NS**	**0.016**	**NS**				

Note: D = Durations, D_1 = Two months, D_2 = Four months, D_3 = Six months, D_4 = Eight months, **T** = Treatment, T_1 = Cloth bag, T_2 = Aluminium foil, T_3 = Brown paper packet, T_4 = Earthen pot, T_5 = Polythene packet, T_6 = Refrigerator.

Dry weight (g): Storage duration varied significantly for the trait, when average was taken over the treatments, though non-significant difference could be noticed among the durations; D_1, D_2, D_3 indicated same magnitude of 0.015 g dry weight and D_4 recorded 0.014 g dry weight (Table 8). Maximum dry weight of 0.016 g was observed by T_5 and T_6 and minimum by T_1 and T_4 (0.013 g), when average was made over durations and it indicated significant variation for the character, though T_1, T_4, T_3 as well as T_2, T_5, T_6 were found to be statistically similar. The result is in agreement with Demir *et al*. (2016) in lettuce and Kavitha *et al*. (2017) in sesame. While analysing the effect of storage period on storage treatments, it revealed non-significant variation for dry weight of seedlings.

Table 8: Effect of storage containers and condition on dry weight (g) of seedlings over the period of storage.

	T_1	T_2	T_3	T_4	T_5	T_6	Mean D
D_1	0.014	0.016	0.015	0.013	0.017	0.017	0.015
D_2	0.013	0.015	0.014	0.013	0.017	0.017	0.015
D_3	0.012	0.015	0.014	0.013	0.016	0.016	0.015
D_4	0.012	0.015	0.014	0.012	0.016	0.015	0.014
Mean T	0.013	0.015	0.014	0.013	0.016	0.016	
	D	**T**	**D X T**				
SEm(±)	**-**	**-**	**0.001**				
LSD (0.05)	**NS**	**0.001**	**NS**				

Note: D = Durations, D_1 = Two months, D_2 = Four months, D_3 = Six months, D_4 = Eight months, **T** = Treatment, T_1 = Cloth bag, T_2 = Aluminium foil, T_3 = Brown paper packet, T_4 = Earthen pot, T_5 = Polythene packet, T_6 = Refrigerator.

Electrical conductivity (dS m^{-1} g^{-1}): Electrical conductivity of seed leachates is negatively correlated with the vigour status of seedlings. As the duration of storage forwarded, electrical conductivity value also increased and significant variation was observed; it was determined highest for D_4 (0.884 dS m^{-1} g^{-1}) and lowest for D_1 (0.237 dS m^{-1} g^{-1}) (Table 9) and with the increase in storage duration, the rate of increase in electrical conductivity was also increased. Autade and Ghuge (2018) noted an increase in electrical conductivity of soybean seeds when period of storage progressed. Among the storage treatments, T_1 showed maximum electrical conductivity (0.577 dS m^{-1} g^{-1}) indicating highest amount of leachates released by the seeds, preceded by T_4, T_3 and T_2, while minimum value of electrical conductivity was recorded for T_6 (0.470 dS m^{-1} g^{-1}), when average was taken over the storage durations and it noted significant variation. Singh and Dadlani (2003) reported that, minimum electrical conductivity might be due to moisture proof container, which results in prevention of fluctuation in seed moisture content and maintenance of high membrane integrity finally reduces lipid peroxidation and prevents release of free radical (Shelar *et al*., 2008). Storage treatment with response to storage period observed significant variation for the trait and it increased with the advancement in storage time, highest conductivity was recorded in D_4T_1 (0.962 dS m^{-1} g^{-1}) and it was noted lowest in D_1T_6 (0.193 dS m^{-1} g^{-1}). Fessel *et al*. (2006) in corn seeds noted least increase in electrical conductivity during storage while stored at a low temperature.

Table 9: Effect of storage containers and condition on electrical conductivity (dS m^{-1} g^{-1}) of seed leachates over the period of storage.

	T_1	T_2	T_3	T_4	T_5	T_6	Mean D
D_1	0.332	0.216	0.222	0.256	0.199	0.193	0.237
D_2	0.416	0.374	0.383	0.403	0.355	0.350	0.380
D_3	0.598	0.537	0.563	0.576	0.531	0.526	0.555
D_4	0.962	0.875	0.894	0.935	0.825	0.812	0.884
Mean T	0.577	0.501	0.516	0.543	0.477	0.470	
	D	**T**	**D X T**				
SEm(±)	**0.001**	**0.001**	**0.002**				
LSD (0.05)	**0.002**	**0.002**	**0.005**				

Note: D = Durations, D_1 = Two months, D_2 = Four months, D_3 = Six months, D_4 = Eight months, **T** = Treatment, T_1 = Cloth bag, T_2 = Aluminium foil, T_3 = Brown paper packet, T_4 = Earthen pot, T_5 = Polythene packet, T_6 = Refrigerator.

Soluble protein content (mg g^{-1}): Storage period showed significant variation for soluble protein content of seeds, when average was made over storage treatments, where maximum value was recorded at D_1 (1.956 mg g^{-1}) and minimum at D_4 (1.296 mg g^{-1}) and a gradual decrease in soluble protein content of seed over the duration of storage was noticed. Similarly the decrease in protein content with increase in storage period was observed by Braccini *et al*., (2000) and Alencar *et al*., (2011) in soybean. Declination in protein content with increase in storage period might be due to ageing and seed deterioration. Among treatments, T_6 was found to be the best performing storage condition indicating highest soluble protein content of seed (1.740 mg g^{-1}), followed by T_5, T_2, T_3 and lowest of it was measured for T_1 (1.411 mg g^{-1}) (Table 10); storage treatments, average over storage durations, performed significantly for the character. The observation is in accordance with Hashmi *et al*. (2001). It has been reported by Singh *et al*. (2017); Orhevba and Atteh, (2018) that the rate of seed deterioration is strongly influenced by the type of container they are stored in. When storage duration was interacted with treatments, significant influence was observed for the trait, where highest soluble protein content of seed was noted in D_1T_6 (2.137 mg g^{-1}) and lowest in D_4T_1 (1.164 mg g^{-1}). Here also, a clear reduction in seed protein content was indicated for every storage treatment as the period of storage forwarded. Ebone *et al*. (2019) concluded that the first event in seed aging is the depression of antioxidant enzymes such as superoxide dismutase (SOD), catalase (CAT), ascorbate peroxidase (APX), and glutathione peroxidase (GPX). The depression of the antioxidant enzyme system was caused by the down-regulation of and reduction in scavenging antioxidant activity (Yin *et al*., 2014). Pukacka and Ratajczak (2007) observed an increased production of reactive oxygen species (ROS) during storage might be due to reduced antioxidant activity, which can degrade soluble protein and reduce enzyme activities and the content of late embryogenesis abundant proteins or small heat shock proteins. These proteins played a protective role in maintaining long storage life of dry seeds (Wolkers *et al*., 2001).

Table 10: Effect of storage containers and condition on soluble protein content (mg g^{-1}) of seed over the period of storage.

	T_1	T_2	T_3	T_4	T_5	T_6	Mean D
D_1	1.790	1.992	1.888	1.812	2.116	2.137	1.956
D_2	1.455	1.615	1.536	1.512	1.743	1.788	1.608
D_3	1.233	1.409	1.325	1.285	1.518	1.586	1.393
D_4	1.164	1.315	1.247	1.214	1.384	1.451	1.296
Mean T	1.411	1.583	1.499	1.456	1.690	1.740	
	D	**T**	**D X T**				
SEm(±)	**0.001**	**0.001**	**0.002**				
LSD (0.05)	**0.002**	**0.002**	**0.005**				

Note: D = Durations, D_1 = Two months, D_2 = Four months, D_3 = Six months, D_4 = Eight months, **T** = Treatment, T_1 = Cloth bag, T_2 = Aluminium foil, T_3 = Brown paper packet, T_4 = Earthen pot, T_5 = Polythene packet, T_6 = Refrigerator.

Total carbohydrate content (mg g^{-1}): When average was measured over the treatments, the mean value of storage durations varied significantly for total carbohydrate content of seeds; it was recorded to be minimum at D_1 with 2.749 mg g^{-1} and increased as the storage duration increased, indicating the maximum value of 3.334 mg g^{-1} at D_4 (Table 11). But after two months of storage, a slight decrease in carbohydrate content was noted for all the storage containers except polythene packet and refrigerator; afterward it increased. Maldonado *et al*. (2015) noted similar trend in carbohydrate content of sugar apple seeds during storage. Average performance of storage treatments showed significant variation; total carbohydrate content was noted to be highest for T_6 (3.197 mg g^{-1}), followed by T_5, T_2, T_3 and it was lowest for T_1 (2.829 mg g^{-1}). Zhang and Lu (2021) noted an increase in invertase activity, reducing sugar and sucrose content of potato tubers due to low temperature storage. Total carbohydrate content of seed was significantly influenced by storage treatments with response to durations; where, maximum carbohydrate content was recorded by D_4T_6 (3.443 mg g^{-1}) and minimum by D_1T_1 (2.510 mg g^{-1}) and a similar trend of increase in the parameter was observed for each treatment as there was progress in storage period. Sucrose and other forms of non-reducing sugars contribute to the structural stability of organelles, membranes, enzymes, and other macromolecules (Obendorf, 1997; Peterbauer and Richter, 2001). In particular, sucrose is effective at protecting cell membranes exposed to desiccation; it is one of the best sugars for vitrification process in plant cells (Bernal-Lugo and Leopold, 1998) because it protects the structure and function of phospholipids during cell drying (Leprince and Buitink, 2010).

Table 11: Effect of storage containers and condition on total carbohydrate content (mg g^{-1}) of seed over the period of storage.

	T_1	T_2	T_3	T_4	T_5	T_6	Mean D
D_1	2.510	2.817	2.740	2.627	2.880	2.923	2.749
D_2	2.580	2.860	2.797	2.670	2.937	3.077	2.820
D_3	3.073	3.373	3.300	3.150	3.417	3.343	3.276
D_4	3.153	3.413	3.350	3.240	3.403	3.443	3.334
Mean T	2.829	3.116	3.047	2.922	3.159	3.197	
	D	**T**	**D X T**				
SEm(±)	**0.005**	**0.006**	**0.013**				
LSD (0.05)	**0.015**	**0.018**	**0.036**				

Note: D = Durations, D_1 = Two months, D_2 = Four months, D_3 = Six months, D_4 = Eight months, **T** = Treatment, T_1 = Cloth bag, T_2 = Aluminium foil, T_3 = Brown paper packet, T_4 = Earthen pot, T_5 = Polythene packet, T_6 = Refrigerator.

CONCLUSION

Just after harvest the seeds, there were no effect of different containers and condition. Among the containers and condition, refrigerated condition was the best as germination percentage, vigour index, soluble protein content of seeds, total carbohydrate content recorded highest and lowest value of electrical conductivity was recorded in refrigerated condition when average over durations. The average germination potential was constantly reduction due to storage *i.e*., 84.11%, 78.35%, 74.12% and 66.85% in second month, fourth month, sixth month and eighth months respectively. Similar trends were recorded in vigour index also.

FUTURE SCOPE

There is a scope to study the effect of different seed treating chemicals during storage in tomato.

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